PLANNING OF ROOFTOP SOLAR POWER PLANTS FOR INTEGRATED CLASSROOM AND LABORATORY BUILDINGS, SILIWANGI UNIVERSITY CAMPUS I

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Abstract *— The need for electrical energy in Indonesia is increasing, while dependence on fossil fuels remains dominant. One potential alternative is the utilization of solar energy through rooftop Solar Power Plants (PLTS). This study aims to design a rooftop PLTS system in the Integrated Classroom and Laboratory Building, Campus 1, Siliwangi University with a technical and economic approach. The research method includes collecting data on load profiles and potential solar radiation, designing system capacity, selecting main components, and simulating using PVsyst software to obtain estimates of energy production and system performance. The planning results show a design capacity of 71,107 Wp with a configuration of 118 solar panels with a capacity of 600 Wp, which produces energy production of around 299–318 kWh per day or equivalent to 109–116 MWh per year. The PVsyst simulation produces an average Performance Ratio value of around 80%, which is in the good category. However, the economic analysis using the Net Present Value (NPV) method shows a negative value (−996,310,000), so this project is not yet financially feasible if implemented in a fully off-grid scenario. In conclusion, the implementation of rooftop solar power plants in the Integrated Classroom and Laboratory Building, Campus 1, Siliwangi University is technically feasible, but not yet financially feasible under current conditions. Therefore, it is recommended to implement a hybrid or on-grid scenario, as well as an electricity tariff sensitivity analysis to increase economic feasibility..*

***Keywords**:* Rooftop Solar Power Plants, Pvsyst, economyc analysis

I. INTRODUCTION

The global electricity demand has surged, largely driven by urbanization, digitalization, and economic acceleration. Correspondingly, rooftop photovoltaic (PV) capacity has experienced remarkable growthnearly doubling in the last three years, reflecting both technological maturation and government incentives [1]. In emerging economies, including Indonesia, the adoption rate of PV systems remains modest: one study of an on-grid 319.4 kWp system notes that actual energy capture is only around 0.7% of installed capacity, indicating significant underutilization and efficiency gaps [2]. The dominance of monocrystalline PV technology in recent years is propelled by its higher efficiency and adaptability, while former high-LCOE regions like Nusa Tenggara Timur are now finding PV financially competitive [3]. Case studies in local contexts also underscore solar's promise: in Palopo, for instance, average solar irradiance of 4.95 kWh/m²/day enables rooftop PV systems to generate electricity efficiently and reduce CO_2 emissions by 0.8 tonnes, showcasing both technical and environmental benefits [4]. Moreover, detailed design analyses including panel sizing and configuration planning using real building load data highlight the increasing sophistication of PV system implementation [5].

In the Indonesian context, the electricity sector remains heavily dependent on fossil fuels, particularly coal, oil, and natural gas. According to national planning documents, more than 82% of Indonesia's electricity supply is still generated from fossil-fuel power plants, while renewable energy contributes less than 20% [6]. This reliance not only increases greenhouse gas emissions but also poses risks to energy security due to fluctuating fossil fuel prices. On the other hand, Indonesia possesses one of the largest solar potentials in Southeast Asia, estimated at 207.898 MW, yet its current utilization is only about 0.04% of the total potential [7]. Government policies have sought to bridge this gap, particularly through the issuance of Presidential Regulation No. 112 of 2022, which aims to accelerate the development of renewable energy-based power plants. Several studies underline that solar energy is highly feasible in the Indonesian context,

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with average irradiation levels of 4–5.5 kWh/m²/day across most regions, making it technically suitable for PV deployment [8]. Nevertheless, the mismatch between potential and actual utilization highlights the urgent need for more effective planning and investment strategies in rooftop PV systems, especially within public institutions such as universities where large building rooftops are available [9].

At an institutional level, universities are ideal candidates for renewable energy demonstration projects due to their extensive building infrastructure and consistent energy demand patterns. Recent research conducted at Siliwangi University's Campus II (Mugasari), located in Tasikmalaya, demonstrates the potential for rooftop solar PV installation using Helioscope simulations. The study includes spatial and irradiance analysis, showing that such installations can significantly contribute to energy generation and greenhouse gas emissions reduction within the campus environment [10] [11]–[13]. Furthermore, large-scale assessments across Indonesia reveal that solar radiation across the nation typically ranges between 3.0 to 5.6 kWh/m² per day, with the southern regions (including West Java) often situated toward the upper end of this irradiation range indicating favorable conditions for PV deployment [14]. Collectively, these findings suggest that the Integrated Classroom and Laboratory Building at Siliwangi University Campus I offers both the technical viability and strategic relevance as a sustainable infrastructure project and a living laboratory for renewable energy education and implementation.

From a technical perspective, designing an effective rooftop PV system requires accurate estimation of load profiles, solar resource availability, and optimal system configuration. Advanced simulation tools such as PVsyst are widely used to model photovoltaic performance by accounting for local climate data, panel orientation, tilt angle, shading, and efficiency losses, thus producing realistic performance predictions [8]. Recent studies in Indonesia have successfully applied PVsyst to estimate annual energy production and performance ratios of rooftop solar power systems, confirming its reliability for academic and practical purposes. However, technical feasibility alone is insufficient to ensure project viability. Financial assessments are equally important, particularly for large-scale rooftop installations. Methods such as Net Present Value (NPV), Life Cycle Cost (LCC), and Payback Period (PP) are commonly used to evaluate investment feasibility and long-term economic benefits. Previous research on rooftop PV installations in Indonesian campuses indicates that, while the systems are technically viable, the economic feasibility is often limited under current electricity tariffs [7]. This highlights the need for hybrid or grid-connected scenarios, as well as sensitivity analyses of tariff policies, to improve economic attractiveness.

Despite a growing body of studies on rooftop solar PV systems in Indonesia, many primarily focus on technical design aspects such as system sizing and performance metrics without adequately addressing financial viability. For example, a techno-economic study on rooftop PV across seven residential building types found that while small systems (around 2.75 kWp) led to negative Net Present Value (NPV) and long payback periods, larger systems (> 7.7 kWp) could achieve positive financial returns under current market conditions [15]. Another case study in Central Java evaluated a mosque rooftop PV installation and highlighted the complex interactions between local electricity tariffs, regulations, and project feasibility but did not fully integrate detailed economic modeling tools like NPV or LCC [16]. Meanwhile, an academic techno-economic appraisal of a university campus PV project abroad demonstrated how integrated PVsyst-based simulations and cost-benefit analysis can inform campus-scale deployment strategies [18]. However, similar comprehensive studies combining technical performance, economic evaluation, and context-specific modeling are still limited in the Indonesian higher education context. This gap underscores the urgent need for case-specific research at institutions like Siliwangi University, to provide robust evidence for planning sustainable rooftop PV systems that are both technically feasible and economically viable.

II. METHODS

The design of this research flowchart is divided into 2 parts, namely, the research stage & the simulation stage, this flowchart is also carried out with several steps as in the following 2 images.

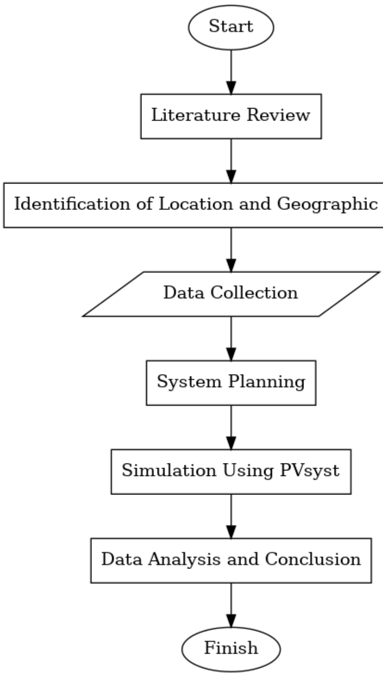

Figure 1. Research *Flowchart*.

Figure 1 show the methodological framework of this study is illustrated through two complementary flowcharts, representing the research stage and the simulation stage. In the research stage, the process begins with a literature review, which aims to identify the current state-of-the-art in rooftop solar PV system design and to establish the research gap. Following this, the location and geographic setting are identified, ensuring that solar resource potential, rooftop availability, and environmental conditions are considered. Subsequently, data collection is conducted, including building load requirements, meteorological data (solar irradiation and temperature), and technical specifications of PV components. Based on these inputs, a system planning phase is carried out to define preliminary capacity sizing, system layout, and selection of key components. The design is then modeled and simulated using PVsyst software, which provides detailed estimations of energy yield, system performance ratio (PR), and expected operational efficiency. Finally, the outputs are subjected to data analysis and conclusion drawing, where the technical results are synthesized with economic considerations to evaluate feasibility.

In the simulation stage, a more detailed design validation process is performed. The stage begins with location identification and continues with the building load requirement setting, which defines the daily and peak energy demands of the studied building. Next, the module orientation and tilt angle are configured to maximize solar energy capture. Based on these inputs, the specification determination is carried out, which includes selecting the appropriate PV modules, inverters, and other balance-of-system components. A simulation is then executed in PVsyst to assess the energy production and system performance. The results are evaluated using the Performance Ratio (PR) metric, with a threshold of 75% applied as a benchmark for acceptable system efficiency. If the PR is below this threshold, the process loops back to adjust the specifications until optimal performance is achieved. Once the PR criterion is satisfied, the simulation stage concludes, and the system design is considered technically feasible. Through these two stages, the methodology integrates both conceptual research planning and iterative simulation-based validation, ensuring that the proposed rooftop PV system design is not only technically accurate but also practically optimized for implementation in the campus environment.

III. RESULTS AND DISCUSSION

This chapter will discuss the results of the planned location for the placement of Solar Power Plants, geographical location, solar irradiation data, building dimension data, and building energy load/needs data.

In planning a rooftop solar power plant, the first step is to measure the roof area where the panels will be installed at the research location. This research was conducted in the integrated classroom and laboratory building on Campus 1, Siliwangi University..

Figure 2. Side view of the integrated classroom and laboratory building, Campus I, Siliwangi University.

Figure 2 is a view of the side/front of the integrated classroom and laboratory building facing eastwards.

Table 1. Dimensional data of the integrated classroom

No	Part	Value
1	Roof length	30,80m
2	Roof width	10,90m
3	Length of the top of the roof	19,40m
4	Roof height	3,20m
5	Building height	11,75m

The next section shows the average GHI value data of 4,96 kWh/m^2/day with a minimum value in July of 4.56 kWh/m^2/day and a maximum GHI value in October of 5.58 kWh/m^2/day.

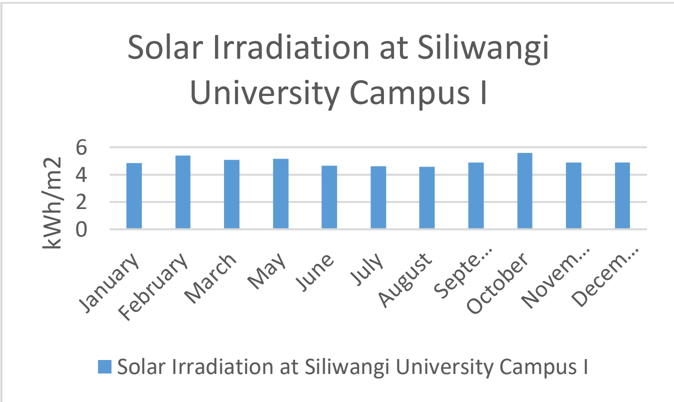

Figure 3. Solar Irradiation Graph of Siliwangi University Campus 1.

The load data for the integrated classroom and laboratory building of Siliwangi University is data taken based on a site survey and based on the load installation planning in the single line diagram. The power of each load is taken based on manual calculations and from reference specifications for each component.

Table 2. Integrated classroom and laboratory building load list.

Component	Amount	Power(watt)/unit	Total Power (watt)
LED light 12W	35	12	420
Downlight 9W	85	9	765
RED RMI light 18W	64	18	1.152
AC cassette	12	4.000	48.000
Electric socket	17	100	1.700
Broadcast and multimedia practice tools	1	2.300	2.300
Regional mapping test practice tools	1	2.300	2.300
Practical tools for physiology and physical fitness tests	1	3.000	3.000
Practical tools for testing drinking water, food and halal	1	3.000	3.000
Amount			62.637 W ≈ 62,6 kW (73,65 kVA)

A. Potential Application of Solar Power Generation on the Roof of the Integrated Classroom and Laboratory Building, Campus 1, Siliwangi University.

1. How to find out how much maximum potential the roof can have with a total area of 336.5 m^2.

$$P_{wattpeak} = PV_{area} \times PSI \times nPV$$
$$P_{wattpeak} = 336{,}5 \times 1000 \times 0{,}228$$
$$P_{wattpeak} = 71.122\ Wp$$

2. Calculate how many solar panels can be used.

$$\text{number of modules} = \frac{p_{wattpeak}}{p_{max}}$$
$$\text{number of modules} = \frac{71.122}{600}$$
$$\text{number of modules} = 118{,}53 \approx 118 \text{ unit}$$

3. Calculate how much energy is produced by the system.

To find out how much energy is produced by the PLTS system, the assumption is that losses are 10%.

$$E_{out} = P_{pv} \times PSH \times Losses$$
$$E_{out} = 70.800 \times 5 \times (100\text{-}10)\%$$
$$E_{out} = 318.600\ Wh$$
$$E_{out} = 318{,}6\ kWh$$

The maximum potential on the roof of the integrated classroom and laboratory building of Siliwangi University is 70.8 kWp using 118 600 wp solar panels and using 4 inverters with a capacity of 15 kW which can produce energy of 318.6 KWh/day with an annual energy of 116.2 MWh.

B. The concept of planning an off-grid PLTS on the roof of the integrated classroom and laboratory building, Campus 1, Siliwangi University.

1. Calculate the array area.

$$\text{PV}_{area} = \frac{Eb}{GHI \times TCF \times n_{pv} \times n_{inv}}$$
$$\text{PV}_{area} = \frac{286.304}{4{,}96 \times 0{,}99 \times 0{,}21 \times 0{,}95}$$
$$\text{PV}_{area} = 295{,}7\ m^2$$

2. Calculating the power generated by solar power plants.

With an array area of 295.7 m^2, Peak Sun Insulation (PSI) of 1000w/m^2, and solar panel efficiency of 22%, the amount of power generated by the PLTS is as follows:

$$P_{wattpeak} = PV_{area} \times PSI \times nPV$$
$$P_{wattpeak} = 295{,}7 \times 1000 \times 0{,}228$$
$$P_{wattpeak} = 62.111\ wattpeak$$

3. Energy produced by the system.

$$E_{out} = P_{pv} \times PSH \times Losses$$
$$E_{out} = P_{pv} \times PSH \times (100\text{-}15)\%$$
$$E_{out} = 62.111 \times 5{,}58 \times 0{,}85$$
$$E_{out} = 294{,}592 \text{ kWh/day}$$
$$E_{TH} = 294{,}592 \times 365$$
$$E_{TH} = 107.526 \text{ kWh/year}$$
$$E_{TH} = 107 \text{ MWh/year}$$

4. Performance Ratio

$$E\ ideal = 62.111 \times 5{,}58$$
$$= 346{,}579$$

$$Performance\ Ratio = \frac{286{,}304}{346{,}579}$$
$$= 0{,}82 \approx 82\%$$

C. Implementation of PVsyst software for solar power plant planning

1. Power generated by the system.

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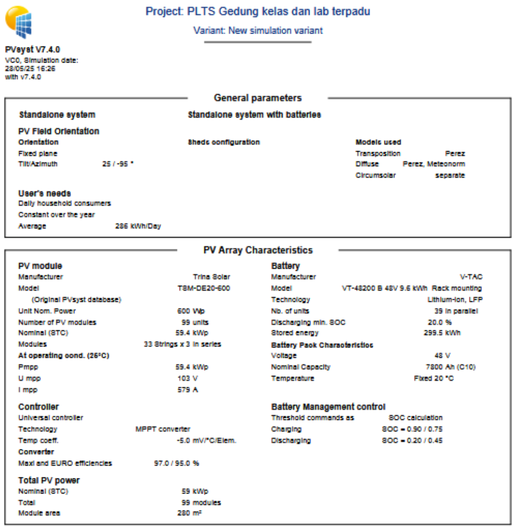

Figure 4. power generated by the system.

The image shows the simulation results in the PVsyst software. The energy generated by the Off-grid PLTS system can be used for the integrated classroom and laboratory building loads based on manual calculations using 39 units of V-TAC 48V 200 Ah batteries arranged in parallel, resulting in a battery capacity of 7800 Ah. These results are almost in accordance with manual calculations, where the total capacity based on manual calculations to meet the building load requirements is 7,608 Ah.

2. Performance ratio.

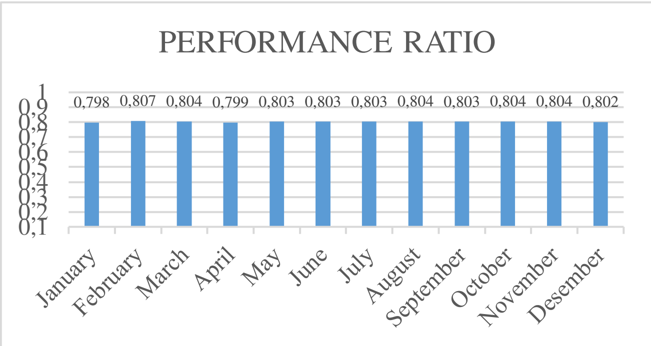

Figure 5. Performance Ratio Graph on PVsyst software

These results are categorized as a good system, as a good solar PV system is categorized as having a performance ratio of around 70%-90%. This result is nearly consistent with manual calculations, which yielded a performance ratio of 82%.

D. Economic Analysis.

The economic analysis of an off-grid solar power plant begins with determining the initial capital cost of installation. Table shows the initial capital cost of an off-grid solar power plant.

Table 3. Initial investment costs.

No	Description	spesification	amount	price	total
1.	Solar PV	Trina TSM-DE20-600	99	Rp. 10.000.000,-	Rp.990.000.000-
2.	Solar pv mounting	Aluminium rail	1	Rp. 15.000.000,-	Rp. 15.000.000,-
3.	Batttery	V-TAC VT-48200B	39	Rp. 29.000.000,-	Rp. 1.131.000.000,-
4.	Inverter	Huawei SUN2000-12KTL-M5	5	Rp. 34.600.000,-	Rp. 173.000.000,-
4.	Converter controller	MPPT 1000W 48V	1	Rp. 2.000.000,-	Rp. 2.000.000,-
5.	Protection	MCB,SPD, FUSE	1	Rp. 5.000.000,-	Rp. 5.000.000,-
6.	Cable	AC, DC, Grounding	1	Rp. 5.000.000,-	Rp. 5.000.000,-
7.	Box Panel	Box Panel	1	Rp. 4.000.000,-	Rp. 4.000.000,-
8.	others	-	1	Rp. 3.000.000,-	Rp. 3.000.000,-
		Total			Rp. 2.328.000.000,-

1. Operational & maintenance cost.

In the solar power plants installation project, there are operational and maintenance costs or what is usually called Operational & Maintenance (O&M).

O&M cost total = (1% dari *Initial Investment*) x 25 tahun

O&M cost total = 23.280.000 × 25

O&M cost total = Rp.582.000.000,00

2. Life Cycle Cost.

Next, it is necessary to know the Life Cycle Cost (LOC) value of the initial capital value and O&M costs during the 25-year service life of the solar power plants.

$LCC = C + O\&M + R$

LCC = Rp. 2.328.000.000,00 + Rp. 582.000.000,00 + Rp.10.500.000,00

LCC = Rp. 2.920.500.000,00

3. Present Worth Factor.

To determine the feasibility of this project, it is necessary to know the Present Worth Factor (PWF) value.

$$PWF = LCC\frac{1}{(1+0.06)25}$$

$$PWF = \text{Rp. } 2.920.500.000{,}00\frac{1}{(1+0.06)25}$$

PWF = Rp. 2.920.500.000,00 (0,2329)

PWF = Rp. 680.184.450,00

4. Cash Flow Benefit & Cash Flow Cost.

With campus electricity class B-3/TM (PLN customer tariff used by large institutions, including campuses/universities), with the highest price of Rp. 1,114.74 per kWh, this can save electricity of.

CFB = Rp. 1.114,74 × 100.599 kWh

CFB = Rp. 112.141.729,26

So

CFB_n = $CFB - O\&M$ tahunan

= Rp. 112.141.729,26 – 23.280.000

CFB_n = Rp. 88.861.729,26

Meanwhile, CFC is the money spent over the 25-year period of the project. Here's the calculation.

$$PV_{O\&M} = \text{O\&M Tahunan} \times \frac{(1+i)^n-1}{i(1+i)^n}$$

$$PV_{O\&M} = 23.280.000{,}00 \times \frac{(1{,}06)^{25}-1}{0{,}06\times(1{,}06)^{25}}$$

$$PV_{O\&M} = 23.280.000{,}00 \times \frac{4{,}2919-1}{0{,}06\times4{,}2919}$$

$PV_{O\&M}$ = 296.820.000,00

$CFC = C + PV_{O\&M} + R$

CFC = 2.328.000.000,00 + 296.820.000,00 + 10.500.000,00

CFC = 2.635.320.000,00

5. Cash Flow Benefit.

To determine whether this project is feasible from an economic aspect, the Net Present Value (NPV) equation is used as follows.

$$NPV = CFB_n \times \frac{(1+i)^n-1}{i(1+i)^n} - C$$

$$= 88.861.729{,}26 \times \frac{4{,}2919-1}{0{,}06\times4{,}2919}$$

PV Benefit = 88.861.729,26 × 12,75

= 1.132.987.048,06

NPV = 1.132.987.048,06 - 2.328.000.000,00

= -1.195.012.951,93

The NPV value obtained is -1,195,012,951.93, which is a value <0, so the project is not feasible from an economic aspect (criteria: NPV > 0 is feasible, NPV < 0 is not feasible.

IV. CONCLUSION

This study shows that the planning of a rooftop Solar Power Plant (PLTS) at the Informatics and Information Systems Classroom Building at Siliwangi University can meet some of the building's electrical energy needs with an installed capacity of 62.6 kWp. Simulation results using PVSyst software show that the system is capable of producing significant annual electrical energy, with the potential for electricity cost savings and carbon emission reductions.From a technical perspective, the solar module configuration, inverter, and system layout have been adjusted to the building's rooftop conditions and the potential solar radiation in the Tasikmalaya area. Economically, a feasibility analysis indicates that rooftop solar power is a viable investment, as it offers positive economic value throughout the project's lifespan. Overall, the implementation of rooftop solar power plants on campus not only contributes to energy efficiency and operational cost savings, but also supports efforts towards a green campus and the implementation of sustainable renewable energy.

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